FERMILAB-Proposal-0549

FNAL Proposal
April 26, 1977
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A Search for Fractional Charges Using Accelerator and Low Temperature Techniques

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Objectives of Experiment

LaRue, Fairbank, and Hebard[1] recently published their finding that two niobium spheres out of 8 studied had charges very close to $\pm 1/3e$. These experiments were done by levitating superconducting niobium spheres approx. 0.2 mm in diameter and carefully measuring their charge by observing the behavior of the sphere when electric fields are applied. These experiments are analogous to the Millikan oil drop experiment but have a sensitivity $\sim 10^7$ times greater than Millikan's for finding a fractional charge. So far the experiments have only used naturally-occuring niobium with no attempt to enrich the "quark" content of the spheres.

It is obviously of great importance to learn more about the source of these fractional charges. Among the important questions to be answered is whether fractional charges can be produced with existing accelerators. It would be a great step forward if a niobium sphere whose charge was known to be integral could be made to capture a fractional charge in a reasonably controlled fashion. We propose to collect fractional charges produced in a high-Z target by a 400 GeV proton beam onto niobium spheres. After the exposure the spheres would be removed from the target vessel and their charge measured at Stanford. If the initial experiments are successful — if we find fractional charges on some of the spheres — detailed studies of yields vs. beam energy and target composition will be possible. Such information can be of great importance in understanding the nature of these fractional charges.

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Proposal Summary

We propose to search for fractional charges using a combination of high-energy and low-temperature techniques. Fractionally-charged particles produced in a liquid (or gaseous) target by a 400 GeV proton beam will be collected on a niobium sphere. The charge of the sphere can then be determined by low-temperature techniques, as in the experiment of LaRue, Fairbank, and Hebard.

Experimental Technique

The experimental arrangement is shown schematically in Figure 1. The target vessel is filled with a liquid or high-pressure gas and an electric field is continuously applied to drive charged particles of the appropriate sign onto the niobium sphere. Ordinary (integrally charged) ions will generally recombine before reaching the sphere, but fractionally-charged ions will be collected on the surface of the niobium with high efficiency.

The success of LaRue, Fairbank, and Hebard in finding fractional charge (which for convenience we can refer to as quarks) and the failure of accelerator and cosmic ray searches which looked for solitary quarks in beams can be explained if quarks are trapped in nuclei. Longo[2] has pointed out that current models for absolute confinement of quarks are likely to break down if the quarks are trapped in large nuclei. This and the fact that both spheres with fractional charge in Ref. 1 had been heat treated on a tungsten plate while most of the others were annealed on a niobium plate suggest that the target for producing the quarks should be a large nucleus. We are tentatively planning to use an aqueous solution of lead perchlorate through other possibilities may be tried as well.[3] This will have a high stopping power for quarked nuclear fragments.

Integrated Fluxes and other Details

We would like to expose at least 12 spheres. Each can be exposed for one to two weeks. This schedule fits naturally into the cycle of maintenance shutdowns at Fermilab. (The measurement of the charge of the spheres is a time-consuming operation and one or two weeks per sphere is about as fast as this can proceed.) We would like to expose the target to the highest possible flux. The most appropriate place to do the irradiation seems to be just ahead of the neutrino production target. Our target is compact and relatively thin ($\sim$10 gm/cm^2) and should not interfere with normal operation in the neutrino area.

Our specific request of the laboratory is to allow us to make approx. 12 one to two week exposures at intensities $\gtrsim 10^{13}$/pulse.[4] Access to the targets to change spheres, etc. will be required. The exposure times are not critical and access can be made at the convenience of the Neutrino Laboratory. Some rudimentary remote-handling equipment to move the target vessel to a less radioactive area will probably be required. We shall seek the advice of laboratory experts on target materials and designs which will minimize heating and handling problems. The niobium spheres, which are not expected to be especially radioactive, will be sent to Stanford for the charge measurements.

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REFERENCES

1. G. LaRue, W. Fairbank, and A. Hebard, to be published in Phys. Rev. Letters.
2. Michael J. Longo, "Do Nuclei with Fractional Atomic Number Exist," UM HE 77-3, Feb. 15, 1977. (submitted for publication in Physical Review Letters).
3. Other considerations that affect the choice of a target material are: (a) The solution (or gas) must not attack niobium and must be a good insulator to minimize plating of material onto the niobium sphere. (b) Any residue left on the sphere should have the minimum possible long-lived radioactivity. Otherwise the measurement of the charge of the sphere would be very difficult.

   Some experimentation will be necessary to find the most suitable material.
4. With 10^{13} protons incident per pulse the beam deposits ~30 J/pulse in the target. A modest amount of cooling capacity will therefore be required.

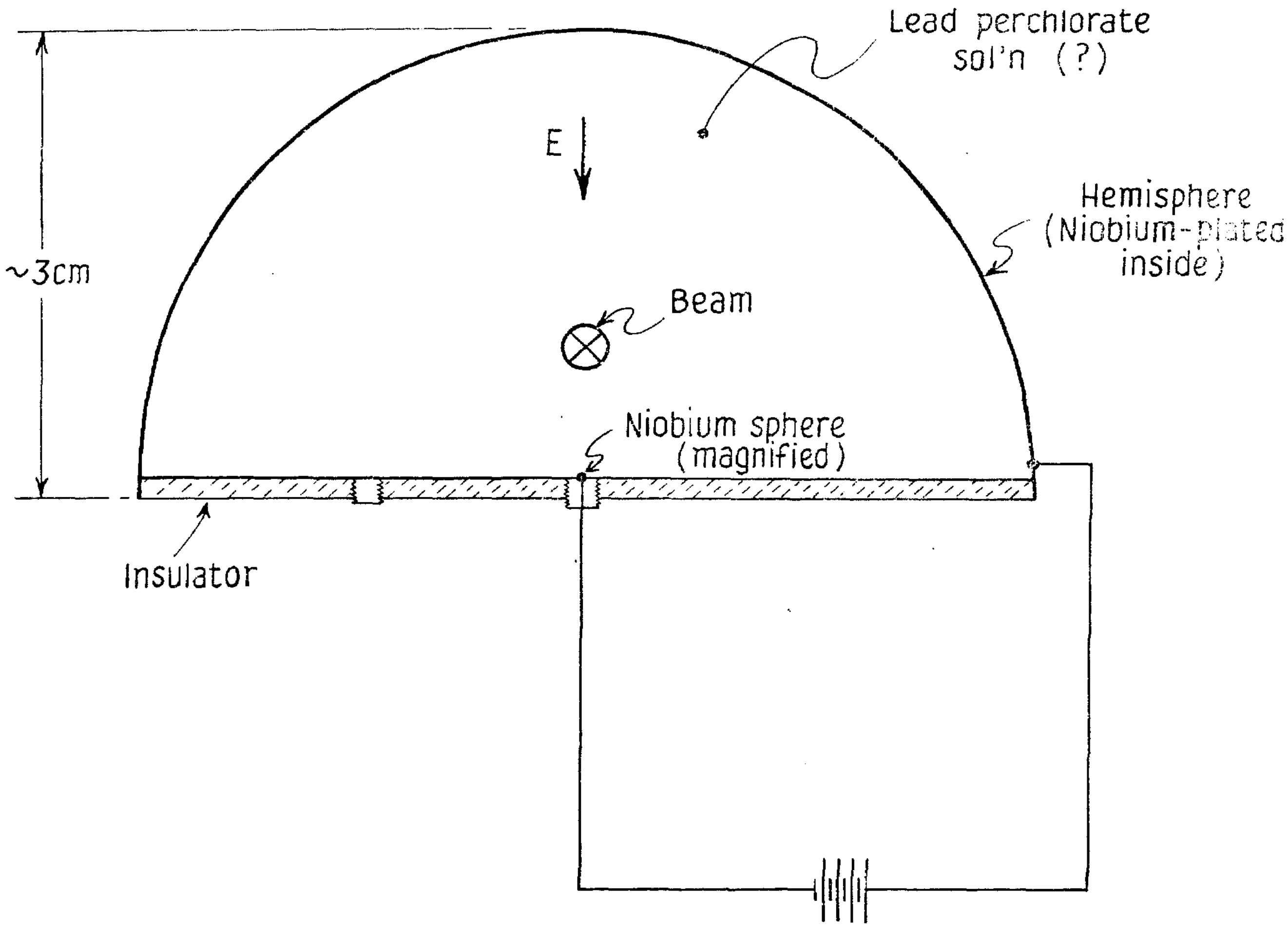

Figure 1 - Schematic